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PRODUCT IMPROVEMENT PROGRAM FOR THE M577 FUZE--VOLUME 4, REDESIGNED TIMER LEVER ASSEMBLY

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
The objective of this project was to design a timer lever assembly which eliminates the lever staff and pallet supports. A design was conceived which combined the aluminum lever staff and pallets supports with the steel lever staff and pallet pins. Because of the required staking operation, the hardness of the lever staff and pallet pins had to be decreased from the current design. Laboratory and environmental testing were performed with satisfactory results. However, after ballistic testing, it was determined the pallet pins were not
(cont)

20. ABSTRACT (cont)

hard enough to withstand the forces in the 155mm, Zone 8 (203 Charge), weapon without bending and affecting the timing accuracy. This design was then dropped from further consideration.

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TABLES

FIGURES

INTRODUCTION

The objective of this task was to redesign the M577 timer lever assembly by combining the lever staff and pallet pins with their supports. Several configurations for the lever staff and pallet pins were investigated. The major concern was finding a material and hardness for the staff and pallets that can be satisfactorily staked and have the strength and durability necessary for the pallet function. The design requirements used were 30,000 g setback acceleration with 30,000 RPM spin.

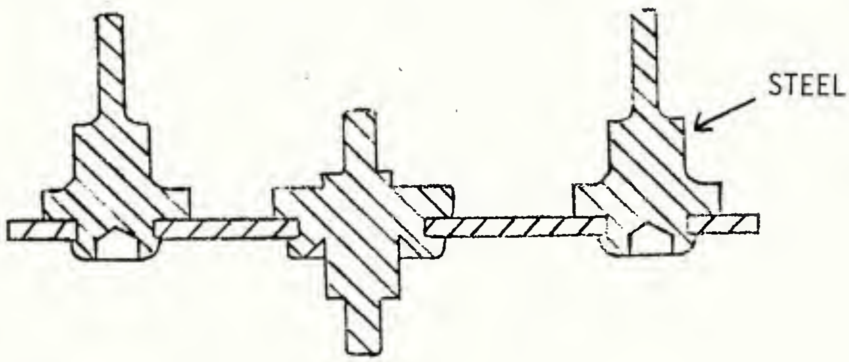
TECHNICAL DISCUSSION

In the current design, shown in figure 1, the steel pallet pins and the steel lever staff are pressed into the aluminum supports. The aluminum supports are staked to a steel lever to form a lever assembly. The proposed design, shown in figure 1, combines the pins and pin supports, the shaft and shaft support so they can be produced as single steel parts.

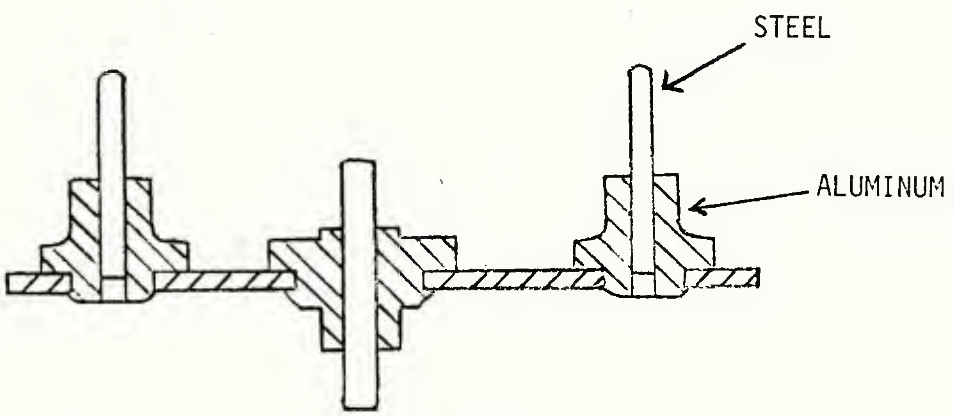
The current design utilizes two materials to take advantage of their different hardnesses. Steel provides strength and durability for the pallet and staff functions, and aluminum provides the required softness to facilitate staking. In the proposed one piece steel design, a compromise in hardness had to be made so that acceptable staking could be achieved. For example, the pallet pins of the current design have a minimum knoop hardness of 542, where as, the proposed design calls for a knoop hardness of 392. In addition, the geometry of the pins, lever staff and staking tools had to be changed to permit acceptable staking. This change in geometry does not affect the function of the lever assembly.

Timers with one piece pallet pin and lever staff assemblies were built and tested for wear on the lever staff and pallet pins. The timers were fully wound and run down ten times. Three of the ten timers tested survived the ten runs; the hairspring broke before the completion of the tenth run in the others. No wear on the lever staff or pallet pins nor change in the position of the pallet pins was observed after the test.

Based on the results of this test, it was decided to environmentally and ballistically test fuzes with one piece lever staff and pallet pins. Environmental tests revealed no problems. Ballistic tests showed more than the normal number of duds in high spin and cold environments. In addition, extremely long times occurred in the 155mm weapon with the M203 charge. This occurrence was not traced to the one piece lever staff and pallet pins until after the



ONE PIECE DESIGN



PRESENT DESIGN

Figure 1 Present and one piece lever assembly design

design was tested in combination with the timer redesign product improvement program. The timer redesign was then tested without the one piece lever staff and pallet pins, and no excessive long times occurred in this test. At this point, the one piece lever staff and pallet pin design was dropped from further consideration. Although it could not be proven in laboratory testing, the failure of the lever one piece staff and pallet pins appears to have occurred because of the decrease in hardness of the pallet pins. A review of the laboratory, environmental, and ballistic testing follows.

TESTING

Spin Tests

Twelve timers with the redesigned timer lever assembly were spin tested from 13,250 to 30,000 RPM. As can be seen in table 1, the beat rate of the timer decreases as the spin speed increases. The average maximum speed at which the timers would operate was 27,800 RPM. After testing, the timers were disassembled and examined for damage; no damage was found. The lever assemblies were inspected and found to be acceptable. Test data are shown in table 1.

Twenty timers with the redesigned timer lever assembly and the timer redesign configuration and three control timers were concentrically and eccentrically spin tested from 13,250 to 30,000 RPM. The test units operated in both concentric and eccentric spin. The control units operated in the concentric spin at 30,000 RPM but in the eccentric spin did not operate at 30,000 RPM. The beat rate decreased at speeds above 22,000 RPM for both test and control units. Test data are shown in tables 2 and 3.

Air Gun Test

Ten inert fuzes, with the redesigned timer lever assembly, were air gun tested from 26,627 to 33,899 g's. Nine of the timers operated after the test; the one that did not had a broken hairspring. This failure is unrelated to the design change. The timers were disassembled, and the timer lever assemblies were inspected. All lever assemblies were found to be acceptable relative to time position and push off of pallet pins.

Jolt and Jumble Test

Twelve fuzes, with the redesigned lever assembly, were built and tested per MIL-STD-331, Tests 102.1 and 101.2. Units were disassembled and examined after the test and found to satisfy the criteria of MIL-F-50983B, Paragraph 4.5.16.

Forty Foot Drop Test

Five fuzes, with the redesigned lever assembly, were built and tested per MIL-STD-331, Test 103.2. Units were disassembled and examined after the test and found to satisfy the criteria of MIL-F-50983B, Paragraphs 4.5.16 and 4.5.18.

Table 1. Spin test results

Clock No.	Beat Rate Before Spin (Beats/sec.)	Amplitude Before Spin (Degrees)	Beat Rate At 13,250 RPM (Beats/sec.)	Beat Rate At 15,650 RPM (Beats/sec.)	Beat Rate At 21,500 RPM (Beats/sec.)	Max. Speed Clock Ran RPM	Condition of Timer Lever After Spin
1	80.71	130	80.63	80.55	80.17	24,500	No damage
2	80.73	123	80.62	80.62	80.07	27,000	"
3	80.73	121	80.62	80.60	80.07	30,000	"
4	80.80	124	80.72	80.72	80.68	25,000	"
5	80.77	120	80.68	80.66	80.17	30,000	"
6	80.70	131	80.67	80.57	79.94	25,600	"
7	80.83	122	80.63	80.60	80.47	30,000	"
8	80.67	126	80.59	80.58	80.60	30,000	"
9	80.66	127	80.56	80.50	80.07	26,000	"
10	80.80	124	80.67	80.64	79.58	28,500	"
11	80.82	126	80.67	80.64	80.69	27,500	"
12	80.69	125	80.57	80.54	80.34	30,000	"

1. Tests conducted at Bulova on September 1, 1981.
2. Amplitude was not recorded during spin.

Table 2. Concentric spin test of combination units

Test date: 1/14/83

	0 RPM BEFORE SPIN TEST		13,000 RPM		15,000 RPM		22,000 RPM		25,000 to 30,000 RPM		0 RPM AFTER SPIN TEST	
TIMER#	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)
1	80.20	124	80.08	85	80.16	115	80.16	120	---	---	80.10	124
2	80.16	126	80.11	125	80.11	123	80.09	120	79.61	120	80.15	126
3	80.11	124	79.93	129	79.91	129	79.91	130	79.76	115	80.08	119
4	80.17	122	80.03	130	80.02	130	80.01	130	79.98	130	80.11	120
5	80.10	122	79.94	130	79.89	135	79.78	135	79.71	125	80.24	113
6	80.16	129	80.04	131	80.06	137	80.08	132	79.91	139	80.04	126
7	80.13	126	79.96	135	79.93	138	79.87	138	79.78	130	79.93	133
8	80.17	120	79.91	129	79.87	130	79.82	130	79.78	130	80.07	119
9	80.23	115	80.02	130	80.01	131	79.93	130	79.85	127	80.21	102
10	80.18	129	80.09	128	80.08	130	80.03	133	80.00	138	80.09	124
*11C	80.67	117	80.62	130	80.62	129	80.61	129	80.50	138	80.57	119
*12C	80.70	120	80.59	120	80.60	122	80.47	121	80.27	140	80.61	120
*13C	80.69	119	80.63	125	80.61	130	80.62	132	80.17	125	80.61	117

--- Indicates absence of data.
* Control Timers (Beat rate range for control timers is 80.74 ± .10 beats/sec.
All other timers, the beat rate range is 80.18 ± .10 beats/sec.

Table 3. Eccentric spin test of combination units

Test date: 1/14/83

TIMER#	0 RPM BEFORE SPIN TEST		13,000 RPM		15,000 RPM		22,000 RPM		25,000 to 30,000 RPM		0 RPM AFTER SPIN TEST	
	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)	BEAT RATE (Beats/Sec.)	AMPLITUDE (Degrees)
1	80.20	124	80.05	132	80.09	135	80.07	132	79.97	138	80.10	124
2	80.16	126	80.16	125	80.16	125	80.05	122	79.78	128	80.15	126
3	80.11	124	79.96	130	79.96	130	79.89	132	79.96	125	80.08	119
4	80.17	122	80.04	130	80.10	130	80.18	120	79.96	125	80.11	120
5	80.10	122	80.16	120	80.16	125	80.16	122	80.16	130	80.24	113
6	80.16	129	80.16	130	80.16	130	80.08	125	80.07	130	80.04	126
7	80.13	126	80.16	125	80.16	125	80.16	122	80.13	130	79.93	133
8	80.17	120	79.96	130	79.99	130	80.13	120	80.14	130	80.07	119
9	80.23	115	80.09	130	80.09	125	80.02	120	79.51	125	80.21	102
10	80.18	129	80.11	130	80.18	130	80.18	130	79.68	128	80.09	124
"11C	80.67	117	---	---	---	---	80.66	122	Timer Stopped		80.57	119
"12C	80.70	120	80.66	125	80.69	138	80.60	125	Timer Stopped		80.61	120
"13C	80.69	119	80.61	125	80.61	130	80.56	122	Timer Stopped		80.61	117

--- Indicates absence of data.
" Control Timers (Beat rate range for control timers is 80.74 ± .10 beats/sec.
All other timers, the beat rate range is 80.18 ± .10 beats/sec.

Five Foot Drop Test

Ten fuzes, with the redesigned lever assembly, and ten control fuzes were built and subjected to the Five Foot Drop Test per MIL-STD-331, Test 111.1. All units had functioning timers after the test.

Ballistic Tests

One hundred fuzes with the redesigned timer lever assembly design and twenty control fuzes were built and ballistically tested at Yuma Proving Grounds. Results showed both reliability and timing problems. Timers of 107.124 and 106.228 seconds were recorded in the 155mm, 198 system weapon set on 105 seconds. Overall reliability was 85%. A summary of the test results is shown in Table 4.

Because of the reliability problem in the ballistic test, a recovery ballistic test of twenty-four fuzes was performed in 155mm, Zone 1 weapon system at -35°F. There were four duds in this test, all of which were timer failures. All the failed timers had the setback pin down and the spin detent had spun out, releasing the balance wheel.

It was decided to perform a special cold verification test to determine the effects of cold temperature on the timer with the redesigned lever assembly. Timers, with current lever assembly design, were built, conditioned for 24 hours at -45°F, and then run for 50 seconds. Timers, whose beat rate or amplitude was outside specifications during 50 second run, were removed from the lot. The remaining timers were rebuilt with redesigned lever assembly and retested in cold environment. Twenty test fuzes were buit using these cold verification test timers, and twenty control fuzes were built with timers having been tested in cold environment. These fuzes were then ballistically tested in the 8 in., M2A1 weapon, Zone 1, -35°F with a setting of 25 seconds. The test fuzes had four duds; the control fuzes had three duds. Test results and dud observations are shown in table 5. It was decided after this test that the timers may have been handled and run too much before they were built into fuzes. Therefore, this test was considered invalid, and the original proposed ballistic plan was continued.

Ninety fuzes, with the proposed timer lever assembly, and ninety control fuzes were built and shipped to Yuma Proving Grounds for ballistic testing. Eighty of the fuzes in each group were tested in September 1982; the RAP round units were not tested until January 1983 because of a shortage of projectiles. The reliability of the test units was 100%; the timing accuracy in all phases was acceptable. A summary of these results is shown in table 6.

Additional testing of the redesigned lever assembly was performed in combination with the 78 Product Improvement Program, Task 3, Timer Redesign.

Table 4. Ballistic test I results

TPR 2594 Supplement 3

LOT #HAT81H000E095 - Test Units

Weapon	Zone	Environment (°F)	Time (Sec.)	Function	Mean	Std. Dev.	LPD
105mm, M103	7	145	50	20/20	50.227	.086	.008
8", M2A1	1	-35	25	13/15	25.008	.099	0
155mm, M185	8	70	75	19/20	75.104	.145	0
155mm, 1985 System	8 (M203)	70	105	15/15	105.363	.397	
					(Outliner excluded)		
105mm, 204 System	8	70	75	11/19	75.259	.298	
175mm, M107	3	70	120	6/10	120.176	.413	

LOT #HAT81H000E068 - Control Units

Weapon	Zone	Environment (°F)	Time (Sec.)	Function	Mean	Std. Dev.	LPD
105mm, 204 System	8	70	75	4/10	75.032	.491	
175mm, M107	3	70	120	4/10	120.671	.508	

Table 5. Cold verification ballistic test

Test Units

Weapon	Zone	Environment (°F)	Time (Sec.)	Function	Mean	Std. Dev.	LPD
8", M2A1	1	-35	25	16/20 [1]	24.953	.058	

Control Units

Weapon	Zone	Environment (°F)	Time (Sec.)	Function	Mean	Std. Dev.	LPD
8", M2A1	1	-35	25	17/20 [2]	24.954	.043	

1. Two duds were recovered; one was an SSD failure, and one was a clock failure.
2. Two duds were recovered; both of these were SSD failures.

Table 6. Ballistic test II results

LOT #HAT82H000E094 - Test Units

Weapon	Zone	Environment (°F)	Set Time	Reliability	Mean	Std. Dev.	LPD
155mm, M185	8	70 TV	50	10/10	49.992	.078	0
155mm, M185	8	70	75	10/10	75.072	.154	0
105mm, M103	7	70	50	10/10	50.065	.043	0
105mm, M103	7	145	50	10/10	50.087	.091	0
8"	1	-35	25	30/30	24.874	.061	0
155mm, 1958 System M483 Projectile	8	70	75	10/10	FIRE FOR EFFECT		
155mm, 1985 System M483 Projectile	8	70	75	10/10	SELF REGISTRATION		
155mm, M198	8 (Rap Round)	+70	95	10/10	94.979	.153	

LOT #HAT82H000E095 - Control Units

Weapon	Zone	Environment (°F)	Set Time	Reliability	Mean	Std. Dev.	LPD
155mm, M185	8	70 TV	50	10/10	49.956	.074	0
155mm, M185	8	70	75	10/10	74.984	.197	0
105mm, M103	7	70	50	10/10	50.083	.054	0
105mm, M103	7	145	50	10/10	50.060	.062	0
8"	1	-35	25	30/30	24.920	.074	0
155mm, 1985 System M483 Projectile	8	70	75	10/10	FIRE FOR EFFECT		
155mm, 1985 System M483 Projectile	8	70	75	10/10	SELF REGISTRATION		
155mm, M198	8 (Rap Round)	+70	95	9/10	94.948	.095	

Sequential Rough Handling Test

Twenty-four fuzes with the redesigned lever assembly and the timer redesign were built for the Sequential Rough Handling Test. A flow chart of the test is shown in figure 2. All units were dropped and inspected according to the flow chart and all but two were subjected to ballistic testing. X-rays, following the five foot drop test, revealed that seven of the twenty-four fuzes had timer setback pins depressed. Because of the large number of fuzes having timer setback pins depressed, two of the fuzes were removed from the lot and torn down for inspection. Both fuzes had the timer setback pin depressed enough to allow the spin detent to prematurely move outward enough to cause a dud. Of the twenty-two fuzes shipped for ballistic, ten units were duds including the ones that had timer setback pins depressed. Ballistic data are included in table 8.

Transportation Vibration Test

Ten fuzes, containing the redesigned lever assembly and timer, were built and tested per MIL-STD-331, Test 104, Procedure 2. These units were then ballistically tested in the 155mm, M185 weapon. Ballistic data are included in table 7.

Combination Ballistic Test

The first ballistic test, combining the redesigned lever assembly with the timer redesign, was performed in January 1983. Seventy-five test fuzes and 75 control fuzes were tested. An extremely long time again occurred in the 155mm, 198 system weapon in a test unit. The reliability of the test group was 96%. A summary of the test results is shown in table 8.

A second combination ballistic test of 230 test fuzes and 200 control fuzes was performed. The test lot included fuzes that had been subjected to Sequential Rough Handling and Transportation Vibration Tests. The results of these tests are discussed in separate paragraphs. Four 105mm recovery vehicles were fired and recovered. The eight fuzes in these recovery vehicles were found to have functioned properly when examined after the test.

Four test units tested in the 155mm, M198 System, 105 seconds, had excessively long times. Because this phenomenon had occurred twice previously with the redesigned lever assembly and never without it, it was decided to perform a diagnostic test. A summary of the combination ballistic results is shown in table 7.

A diagnostic test plan was designed to determine which part of the design was causing the excessively long times. All testing was done in the 155mm, M198 System, Zone 8 (M203 charge), -50°F, 105 seconds. The plan consisted of the following test groups:

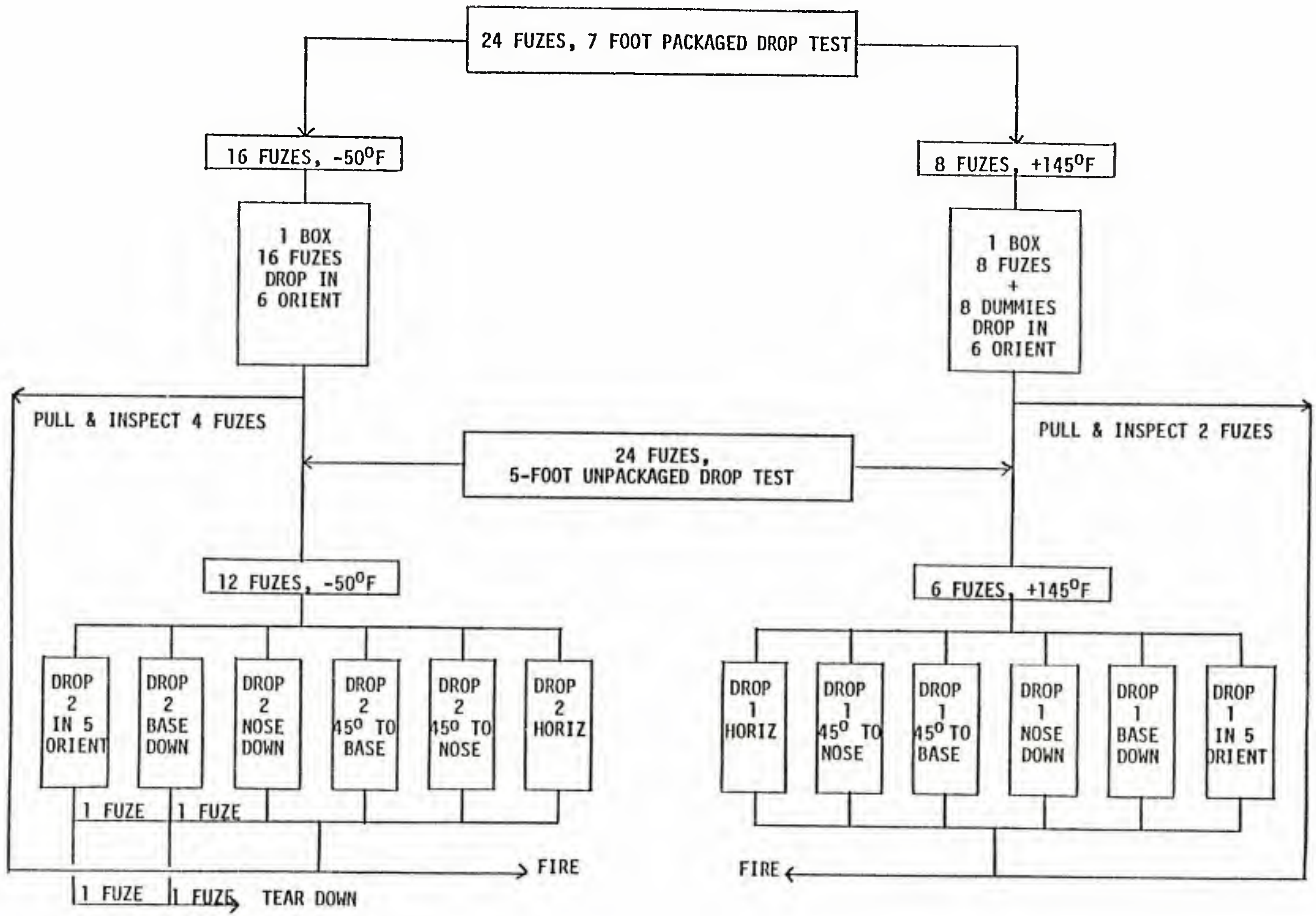


Figure 2. Sequential rough handling flow chart

Table 7. Ballistic test II results of combination timers

WEAPON	ZONE	Environ-ment (°F)	SET TIME	REL	MEAN	STD. DEV.	LPD
(1) 155mm, M185	8	+70	75.0	20/20	74.961	.134	0
(2) 155mm, M185	8	+70	75.0	20/20	75.071	.171	.021
(1) 155mm, M198	8(M203)	+145	105.0	8/10	105.217	.503	
(2) 155mm, M198	8(M203)	+145	105.0	10/10	105.161	.340	
(1) 155mm, M198	8(M203)	-50	105.0	9/10	105.556	1.233	
(2) 155mm, M198	8(M203)	-50	105.0	10/10	104.766	.250	
(1) 155mm, M198(549)	8(M203)	+70	50.0	10/10	50.140	.152	0.98
(2) 155mm, M198(549)	8(M203)	+70	50.0	10/10	50.097	.112	0
(1) 155mm, M185	8	+70 TV	50.0	19/20	50.066	.080	0
(2) 155mm, M185	8	+70 TV	50.0	20/20	50.063	.062	0
(1) 155mm, M103	7	+70	50.0	19/20	50.143	.117	.172
(2) 105mm, M103	7	+70	50.0	20/20	50.108	.098	0
(1) 105mm, M204	8(XM200)	+145	75.0	12/15	75.174	.150	.018
(2) 105mm, M204	8(XM200)	+145	75.0	14/15	75.270	.109	0
(1) 105mm, M103	7	+145	50.0	20/20	50.077	.81	0
(2) 105mm, M103	7	+145	50.0	20/20	50.102	.078	0
(1) 8inch, M110A2	9(M188)	-50	105.0	10/10	104.724	.237	
(2) 8inch, M110A2	9(M188)	-50	105.0	10/10	104.868	.139	
(1) 8inch, M110A2	9(M188)	+145	105.0	10/10	105.083	.173	
(2) 8inch, M110A2	9(M188)	+145	105.0	10/10	105.160	.127	
(1) 8inch, M2A1	1	+70	15.0	18/20	15.005	.094	0
(2) 8inch, M2A1	1	+70	15.0	20/20	15.008	.071	0
(1) 8inch, M2A1	1	-35	25.0	19/20	24.911	.077	0
(2) 8inch, M2A1	1	-35	25.0	20/20	24.895	.091	.011
(1) 155mm, M198(483)	8(FFE)	+70	40.0	20/20	40.34	.20	Stop Watch Times
(2) 155mm, M198(483)	8(FFE)	+70	40.0	15/15	40.29	.10	Stop Watch Times
(3) 105mm, M103	7	-50	50.0	8/16	49.907	.074	
(3) 105mm, M103	7	+145	50.0	4/6	50.006	.295	
(4) 105mm, M103	7	+70	50.0	4 ea. recovery vehicles fired and recovered			

*Legend:

(1) HAT - 83H000E061 - Test Rds - Assembled with complete timer redesign.

(2) HAT - 83H000E119 - Control Rds.

(3) HAT - 83H000E064 - Test Rds - Sequential Rough Handled.

(4) HAT - 83H000E120 - Test Rds - 105mm Recovery Vehicles.

Table 8. Ballistic test I results of combination units

LOT #HAT82M000E060 - Test Units

Weapon	Zone	Environment (°F)	Set Time	Reliability	Mean	Std. Dev.	LPD
155mm, M198	8 (FFE)	+70	75	10/10	75.115 [1]	.077	
155mm, M198	8 (SR)	+70	75	10/10	74.979 [2]	.067	
155mm, M185	8 (M119CHG)	+70	75	14/15	74.970 [2] (Outliner excluded)	.148	0
155mm, M198	8 (M203	+70	100	14/15	100.114	.282	
105mm, M103	7	145	50	14/15	50.135	.096	0
155mm, M198	8 (Rap Round)	70	95	10/10	95.148	.166	

LOT #HAT82M000E096 - Control Units

Weapon	Zone	Environment (°F)	Set Time	Reliability	Mean	Std. Dev.	LPD
155mm, M198	8 (FFE)	+70	75	10/10	75.042 [1]	.074	
155mm, M198	8 (SR)	+70	75	10/10	74.964	.135	
155mm, M185	8 (M119 Chg)	+70	75	15/15	74.999	.094	0
155mm, M198	8 (M203)	+70	100	15/15	100.066	.266	
105mm, M198	7	145	50	15/15	50.056	.075	0
155mm, M198	8 (Rap Round)	+70	95	10/10	95.076 [4]	.095	

1. Chronographs failed to record time on 6 of the 10 units tested.
2. One fuze time was lost on chronographs.
3. Chronograph failed to record time on three of the rounds.
4. Chronographs failed to record time on 2 of the rounds.

Table 9. Diagnostic ballistic test results

155MM, M198,Z8, M203 CHG, M101 PROJ, -50^{o}F, 105.0 SEC

	FUNCTION	MEAN	STD. DEV.
Group I	20/20	104.810	.316
Group II	10/10	104.840	.335
Group III	8/10	104.827	.244
Group IV	7/10	104.832	.446
Group V	13/15	105.078	.411

Group	Configuration
I	die cast plate no. 1 and lower plate, external drive gear, standard lever pallet pins and staff
II	die cast plate no. 1 and lower plate, external drive gear, Westclox escapement, standard lever pins and staff
III	die cast plate no. 1, lever one piece pallet pins and staff
IV	die cast plate no. 1 and lower plate, external drive gear, lever one piece pallet pins and staff (left over from previous ballistic test)
V	control

No unusually long times occurred in any of the groups for this test. However, duds occurred in both groups containing the lever one piece pallet pins and staff. Ballistic data for all groups are shown in table 9.

CONCLUSIONS AND RECOMMENDATIONS

It was decided after the diagnostic ballistic test to discontinue the development and testing of the lever one piece pallet pins and staff. The decrease in the hardness of the pallet pins necessary to stake the one piece assemblies appeared to be the reason for the long times and duds in the ballistic tests. Testing of the timer redesign and Westclox escapement was continued under another contract with excellent results.

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